AN ABSTRACT OF THE THESIS OF

Samantha M. Ross for the degree of Master of Science in Exercise and Sport Science, presented on May 27, 2015

Title:
Motor Skill Proficiency, Performance and Participation in Children with Physical Disabilities

Abstract approved:

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Megan MacDonald

Background: Mastery of fundamental motor skills (FMS) in childhood is proposed to facilitate participation in physical activity (PA) opportunities, through context-specific application of FMS (Clarke & Metclafe, 2002; Stodden et al., 2008). Children with disabilities impacting motor skill development thus are at greater risk for low PA participation. Evidence indicates significantly lower levels of physical activity among children with physical disabilities compared to peers (Law et al., 2006). However, only a few studies have examined the direct association between this participation discrepancy and FMS within this population, (e.g. Capio, Sit, Abernethy, & Masters, 2012) and the influence of FMS performance during activity on this pathway has not been systematically examined. Purpose: To identify underlying mechanisms for low PA participation relative to motor skill development in children with physical disabilities. Specifically, the mediating effect of motor skill performance on the relationship between FMS proficiency and PA participation level was examined. Methods: Ten children with disabilities were assessed around one time-point in FMS proficiency, FMS performance during a structured activity opportunity, and PA levels, as measured by accelerometry and direct observation. The mediation model was statistically tested using the ordinary least squares approach (Hayes, 2013). Results: PA level, as measured through direct observation, was significantly accounted for by the effect of motor skill proficiency through motor skill performance (*95% CI* [0.001 – 0.009]). Conclusion: Findings lend initial evidence that among children with physical disabilities observed during a structured PA opportunity, proficiency in motor skills influences rate of skill use, which in turn facilitates greater observed PA levels. Knowledge of this indirect pathway to participation has implications for PA promotion strategies and contributes to the broader discussion of the impact of disability on participation.

Motor Skill Proficiency, Performance and Participation
in Children with Physical Disabilities

by
Samantha M. Ross

A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented May 27, 2015
Commencement June 2015

Master of Science thesis of Samantha M. Ross presented on May 27, 2015.

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Samantha M. Ross, Author

ACKNOWLEDGEMENT

The author expresses sincere gratitude for the support and guidance of her advisor, Dr. Megan MacDonald and thesis committee, Drs. Sam Logan, Heidi Wegis and Viktor Bovbjerg. Additional gratitude is extended to research assistants Allison Conger, Haylee Winden and Megan Mulcahy for substantial help in data collection and processing. All have been extremely generous with their time, insights and contributions to the project. Even more so, all have shared enthusiasm and support along the way, making this a very enjoyable experience!

A sincere thank you goes to fellow graduate students Laynie Case, Kiley Tyler, Erica Twardzik, Amanda Tepfer and Willie Leung for being a sounding board for ideas and supporting the development of this project. I could not have completed this without your support! And, last but not least, a warm and loving “thank you everything you do” to family and loved ones for being there every step of the way and providing much needed moral support.

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Chapter 1: Introduction

Physical activity (PA) participation is gaining attention as a viable strategy for promoting optimal health and well-being and for the prevention of secondary conditions in children with and without disabilities (U.S. Department of Health and Human Services, 2008; Murphy, Carbone, & the Council on Children with Disabilities, 2008; Rimmer, 1999). Further, involvement in PA supports psycho-social development, such as self-esteem, self-efficacy and peer relationships for children with disabilities (Taub & Greer, 2000). This is of considerable concern that children with disabilities experiencing delays in motor function, such as cerebral palsy, spina bifida and non-progressive muscular dystrophy, report significantly lower PA levels compared to typically developing peers (Law et al., 2006; Maher, Williams, Olds, & Lane, 2007; Zwier et al., 2010). Not only are participation levels low within this group, but the majority of children with disabilities report not meeting national recommendations for average time spent daily in moderate-to-vigorous physical activity (MVPA), with a greater portion of PA time reported in informal, solitary activity compared to formal, skill-based activity (Law et al., 2006; Maher et al., 2007; Zwier et al., 2010). For instance, a child with a physical disability is more likely to report having gone on a walk or played with a pet in the last week, than having participated in a sports game or organized activity (Law et al., 2006). This trend jeopardizes children's opportunity to reap activity related developmental benefits, such as positive peer interactions and gains in self-efficacy (Taub & Greer, 2000), and health benefits, such as cardiorespiratory endurance, muscular strength and reduced risk for secondary conditions (Fowler et al., 2007).

PA as it relates to health and disability is most appropriately framed within the *International Classification of Functioning, Health and Disability* (ICF) (Ploeg, Beek, Woude, &

Mechelen, 2012; Rimmer, 2006; Temple, 2010; World Health Organization, 2001). The ICF will be defined in more depth in chapter 2, but in brief, an individual's overall health is modeled as a dynamic interaction between body function/structure, activity and participation, and social-contextual domains (Jette, 2006; WHO, 2001, 2013). Figure 1 illustrates how PA maps onto the ICF framework.

In alignment with the ICF body function and structure domain, PA has been discussed at the individual level in terms of fitness (muscular strength and endurance, coordination, cardio-respiratory endurance, etc.) (McBurney, Taylor, Dodd, & Graham, 2003) and disability-specific characteristics, such as spasticity, incontinence and fatigue (Rimmer, 2006; Temple, 2010). The activity domain captures the execution of skills or tasks and may be operationalized for PA as gross motor function level or the performance of functional tasks on a daily basis (e.g. Palisano, Copeland, & Galuppi, 2007), or *during* activity opportunities (e.g. Logan, Robinson, Webster, & Barber 2013). Participation, the third health domain, describes social involvement or the degree to which a child engages in culturally relevant roles within the community, such as being a member of a sports team and engaging in play dates and recreational activity with peers (Mallinson & Hammel, 2010; WHO Organization, 2001). Common definitions of participation in disability literature include frequency of reported attendance in structured (i.e. organized sport and recreation) and informal, leisure activities (e.g. Palisano et al., 2007; Maher et al. 2007; Law et al., 2006); intensity of physical engagement in relation to time spent in sedentary, light and MVPA categories (e.g. Clanchy, Tweedy, & Boyd, 2011; Hinckson & Curtis, 2013); self-rated enjoyment of and satisfaction with involvement in recreational activity opportunities (e.g. King et al., 2006); and time spent attentive to or thinking about what is happening during the activity (Maxwell, Augustine, & Granlund, 2012).

The activity and participation domains can be further qualified as capacity, performance and involvement (Badley, 2008; Granlund et al., 2012; WHO, 2013). These are offered to differentiate between a child's optimal execution of an act or skill without consideration for context (i.e. *activity capacity*), performance of goal-oriented tasks or skills within the context of daily living (i.e. *activity performance*), and the degree to which children perform tasks and skills to fulfill personally and socially meaningful goals in life situations (*i.e. participation involvement*) (Badley, 2008; Coster & Khentani, 2008; Granlund et al., 2012; Whiteneck & Dijkers, 2009; WHO, 2013). These dimensions of PA interact to impact the child's overall PA experience and thus, should be considered together when investigating the PA patterns of children with disabilities at the individual and population level.

[Insert figure 1]

To date, however, few studies have directly examined the relationship between ICF domains as it relates to PA. Traditionally, low participation in PA (defined as intensity, frequency and diversity of attendance in activity opportunities) among children with disabilities has been directly attributed to individual deficits within the activity capacity domain. In other words, traditional medically-based disability models have examined the direct link between what a child with a disability is able to optimally achieve in a clinical setting and poor participation outcomes, with minimal consideration for how disability impacts function in the context of daily living. One primary activity limitation of interest for children with physical disabilities has been fundamental motor skills (FMS) capacity. Throughout the remainder of this manuscript 'FMS proficiency' will be used to refer to a child's capacity to execute a set of rudimentary locomotor and object control skills commonly used in sport and recreation, such as running, jumping, kicking and catching (Clark & Metcalfe, 2002; Stodden et al., 2008). Research supports that for typically developing children, FMS proficiency serves as a positive predictor for time spent in moderate-to-vigorous physical activity (MVPA: i.e. participation level) (Fisher et al., 2005; Lubans, Morgan, Cliff, Barnett, & Okely, 2010; Stodden & Goodway, 2007; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). Children who demonstrate greater mastery of FMS are significantly more likely to report a greater amount of time spent in PA daily (Fisher et al., 2005; Wrotniak et al., 2006). Children with disabilities, however, are largely underrepresented in this literature, with similar trends having only been observed in a small sample (n=31) of children with cerebral palsy (Capio et al., 2012).

While findings suggest a direct pathway between FMS proficiency and PA participation domains, the relationships tend to be relatively weak and non-linear (Fisher et al., 2005), with stronger correlations with PA levels among children performing in the lowest and highest quartiles of motor skill proficiency (Wrotniak et al., 2006). That is, skill mastery seems to account for the relatively high PA levels among highly-skilled children and account for a disproportionality low PA levels of children who experience motor skill deficients. Children with physical disabilities tend to perform, as a group, in the lowest quartile (Ulrich, 2000) and subsequently, poor motor skills may account for the discrepancies in PA participation compared to typically developing peers. However, the paucity of literature inclusive of children with disabilities cautions this conclusion. Furthermore, in alignment with the ICF framework, there is a critical need to examine how performance patterns in the context of PA influences this relationship. In sum, the large discrepancies in PA levels for children with disabilities warrants further investigation of the extent to which motor skill proficiency relates to PA levels and the mechanisms associated with this pathway when context is taken into consideration. Accordingly, the primary purpose of this study is to investigate the direct and indirect relationships between

FMS proficiency, motor skill performance during PA and PA levels among children with physical disabilities, as framed within the ICF.

The relationships between ICF activity and participation domains as it relates to PA has been discussed within motor developmental system models. The mastery of isolated FMS is suggested to enable a child to develop more complex movement patterns and utilize those skills within the context of sports and recreational activity, in turn facilitating a child's accruement of sufficient time in MVPA (i.e. higher PA level) (Clark & Metcalfe, 2002; Stodden et al., 2008). Wall's (2004) "activity deficit hypothesis" further states children with movement difficulties, such as children with physical disabilities, will find it increasingly more difficult to engage in PA at the level of their peers as they age and the skill demands for activity participation increases. In other words, intensity of participation in PA is modeled to be directly linked to the translation of motor skill capacity (what skills a child *can* do in isolation) to motor skill performance (skills execution during an activity), with the gap in participation between children of varying skill levels increasing with age and development. This conceptual model is illustrated in figure 2A, alongside the corresponding statistical model in figure 2B, and can be considered as an indirect pathway in which the effect of FMS proficiency is predicted to be mediated by motor skill performance during activity.

[Insert figure 2]

Several key studies have revealed evidence in support of this mediation model for children with physical disabilities. First, in support of the direct pathway from capacity to PA participation, children with severe or physical disabilities demonstrating low motor skill proficiency or overall low gross motor function have been shown to report significantly lower participation rates in structured, high intensity and skill-based sport and recreational activities compared to peers (Law et al., 2006; Maher et al., 2007; Palisano, Copeland, & Galuppi, 2007;. Palisano et al., 2011). More targeted investigations have shown direct positive associations between FMS and time spent in MVPA among children with cerebral palsy and intellectual disabilities (Capio et al., 2012; Westendorp, Houwen, Hartman, & Visscher, 2011). Second, evidence for the relationship between activity capacity and performance have shown individual's gross motor functional level to positively relate to the likelihood a person will report being able to, and routinely performing, daily gross motor tasks (Holsbeeke, Ketelaar, Shoemaker, & Gorter, 2009; Young, Willians, Yoshida, Bombardier, & Wright, 1996). Notably, greater variability is observed for score distributions on gross motor performance compared to capacity scales within the same sample, supporting capacity and performance as distinct activity domains and emphasizing the influence of context (clinical vs. home-life) in activity patterns (Holsbeeke et al., 2009; Young et al., 1996). Third, Bjornson and researchers (2013) expanded this work to reveal evidence in support of a mediating effect. Researchers found that 74% of the variance in social participation at school, home and in neighborhood among children with cerebral palsy could be accounted for by the indirect effect of gross motor capacity and daily performance (Bjornson, Zhau, Stevenson, & Christakis, 2013). In other words, for two children equivalent in capacity to demonstrate gross motor tasks in the clinical setting, the difference in their social participation was significantly explained by how often they actually performed gross motor tasks daily. Motor developmental models map a parallel pathway from FMS proficiency (run, jump, catch, etc.) to participation in MVPA through routine performance of motor skills within activity settings (see Figure 2). To date, however, this mediation model, as it relates to specific motor skills and PA, has not been systematically examined.

Accordingly, the specific aim of the present study is to examine if motor skill performance during structured PA opportunities mediates the relationship between FMS proficiency and PA levels in children with physical disabilities. It is hypothesized that motor skill performance will strengthen the association between proficiency and PA levels among children with physical disabilities. In effect, findings may provide preliminary description of 'how' motor skill proficiency relates to PA participation levels, with the prediction that greater motor skill proficiency will translate to higher number of motor skills performed while engaged in a structured opportunity, promoting higher intensity of PA participation. As such, the indirect pathway through motor skill performance will significantly account for variance in participation levels.

In sum, effective intervention strategies are needed to increase the drastically low levels of PA participation among children with physical disabilities. One potential avenue is through the targeted development of FMS. Currently, however, the literature and contemporary disability models do not support a strong direct effect of FMS proficiency (what a child does in a controlled setting) on PA participation levels. Alternatively, it may be more relevant to examine an indirect pathway mediated by motor skill performance, in which context is taken into consideration (i.e. motor skill use during PA). Focus on function in child-relevant settings aligns with ICF emphasis on person-environment interactions as primary indexes of health and well-being. This discussion will be rooted in motor developmental approaches (Clarke & Metclafe, 2002; Stodden et al. 2008) and framed within the ICF conceptual model (WHO, 2001). An introduction to defining fundamental motor skill performance as it aligns with our framework occurs in Chapter 2: Literature Review and is expanded on in Chapter 3: Methods, including an outline for quantitatively measuring skill performance. This study aims to test the mediating effect of motor skill performance on the relationship between FMS proficiency and PA participation for children with physical disabilities. Redirecting attention to activity performance will lay the foundation for more extensive investigations and discussion of the mechanisms contributing to low PA participation within structured activity opportunities within this population. A more comprehensive understanding of this pathway to participation may inform intervention strategies for increasing PA and promoting optimal health outcomes for children with disabilities experiencing activity limitations.

Definitions

Fundamental motor skill proficiency: Capacity of a child to complete a set of locomotor and object control skills, in a controlled setting, using a movement pattern consistent with specific performance criteria.

Fundamental motor skill performance: Achievement of locomotor and object control skills during engagement in structured physical activity that meet both align with the goal of the activity and are performed in a movement pattern broadly consistent with specific skill criteria.

Structured physical activity: Organized, goal-oriented activity that is facilitated by an instructor or teacher, in which a specific skill set is required for full participation

Physical activity participation level: time of activity engagement spent in pre-determined intensity categories for moderate-to-vigorous.

Purpose Statement

The purpose of the present study is to examine the extent to which fundamental motor skill (FMS) performance, as measured by frequency of skill use during structured physical activity (PA), mediates the relationship between FMS proficiency and PA levels in children with physical disabilities.

The central hypothesis of this study is that FMS performance during structured PA will mediate the relationship between FMS proficiency and PA levels in children with physical disabilities. Better FMS proficiency is predicted to be associated with greater frequency of FMS performance (i.e. skill use during structured activity), and thereby strengthen the positive association between FMS proficiency and PA levels.

Specific Aim and Hypothesis: To examine if FMS performance during structured PA opportunities mediates the relationship between FMS proficiency and PA levels in children with physical disabilities. It is *hypothesized* that *FMS* performance will act to strengthen the association between FMS proficiency and PA levels among children with physical disabilities.

Assumptions and Limitations

Underlying assumptions of this study relate to the direct relationship of motor skill proficiency on PA levels and assessments being used to define motor skill proficiency and performance. FMS proficiency is assumed to be positively correlated with average time spent in daily moderate to vigorous physical activity for children with physical disabilities, based on trends observed in typically developing children (Fisher et al., 2005; Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). However, testing the mediating model is not contingent on this assumption being met or a significant relationship between the predictor and the outcome variable under the new PROCESS approach (Hayes, 2009; 2013). Second, it is assumed that children will put maximum effort forth when performing the motor skill assessments and that those scores are representative of maximum motor skill capacity. Further, it is assumed that during participation, children with physical disabilities will be highly motivated to perform motor skills and the structured PA program will facilitate ample opportunity and support for performance of targeted skills. It is assumed that the proposed FMS performance qualifiers appropriately capture motor skill attempts in children with physical disabilities. Children may adopt modified movement patterns to account for functional constraints to facilitate optimal participation. As a result, the performance qualifier of consistency with ‘mature’ movement patterns (i.e. performance criteria) established based on typically developing children (Ulrich, 2000) may not adequately represent skill performance in this population. Additionally, poor comprehension of the task goal or required skills may result in a child performing an inappropriate skill attempt unintentionally. In the event that the assumptions of this investigation do not hold, an underestimate of FMS attempt frequency is likely to result. Video recording of all participation sessions will allow for secondary video analysis of performance if qualifiers are suspected to be inadequate for describing skill performance in this population. The use of two trained coders, with establishment of inter-rater reliability through pilot testing, will additionally assist in ensuring consensus and consistency in skill performance definitions.

Delimitations

A delimitation of this study is the sample selection and structured PA setting. Participants will be recruited exclusively from an adapted physical activity program at a major University in Oregon, thus biasing the sample to include children with disabilities who live in an active community, are engaging in adapted physical activity weekly and have parents/caregivers supportive of PA. Further, my choice to use as my structured PA setting cautions the generalization of findings to alternative structured PA opportunities, such as recreational and sports activities in the community and in school. This restriction was chosen in effort to control for extraneous factors that may limit performance such as parental beliefs of activity (i.e. not supporting participation through negative attitudes or lack of transportation) and appropriate assistance and support services during activity. In the adapted physical activity program, participants are paired with volunteers (1:1 ratio) and adapted physical education teachers in training that can provide appropriate equipment and activity modifications. Thus, we suspect that these delimitation will allow us to optimally detect the effect of motor skill performance on PA levels.

Significance

An underlying inference of motor developmental models, and traditional disability models, is motor skill proficiency, occurring at the individual level and in the absence of context, can account for PA participation discrepancies between children with and without disabilities. However, contemporary disability (WHO, 2001) and development models (Clark & Metcalfe, 2002; Stodden et al., 2008), in recognition of the influence of environment individual behavior patterns, argue that individual performance of skills in the context of daily living is a more appropriate index of health and development. In relation to PA, FMS proficiency is posited to support the development of complex, content-specific motor patterns performed during structured activity, which in turn facilitates achievement of higher PA participation levels in children. However, little evidence exists to explicitly support an indirect pathway and the mediating effect of motor skill performance in the context of structured activity in children with physical disabilities. Thus a comprehensive investigation of the mechanisms for PA participation specific to this population and framed within the ICF is warranted. *The present research is significant in that outcomes will assist in quantifying motor skill performance during PA in relation to skill proficiency and PA participation among children with physical disabilities. These findings will contribute to the existing literature on the dynamic association between ICF health domains. Specifically, the relationship between motor skill proficiency, performance and PA participation levels.* Expected outcomes will inform our knowledge of potential mechanisms accounting for the discrepancy in structured PA participation among children with physical disabilities compared to typically developing peers. Evidence in support of FMS performance as a mediator for the direct effect of motor skill proficiency on PA participation would suggest focus on FMS performance (what skills as child does use in the context of PA) as a viable strategy for increasing participation levels. Findings from the present study will serve to initiate discussion on how to define activity performance for children with physical disabilities as it relates to motor skills, PA participation and health. This has potential to subsequently inform approaches to increasing PA and the development of viable strategies for optimizing health outcomes among this at risk population.

Chapter 2: Literature Review

Introduction

Of immediate public health concern are the significantly lower levels of physical activity reported among children with physical disabilities, compared to levels among typically developing peers (Law et al., 2006; Maher et al., 2007; Zwier et al., 2010). Children with physical disabilities are, as group, at greater risk for secondary conditions such as cardiovascular disease (Fowler et al., 2007). Engagement in physical activity childhood has been shown to ameliorate this risk (Warburton, 2006). Thus, it is imperative that we address this discrepancy in childhood and develop appropriate and effective PA promotional strategies specific to children with physical disabilities.

The development of PA interventions requires a comprehensive understanding of the unique determinants and pathways of PA participation for children with physical disabilities. Discussion of these factors, as they pertain to individuals with a disability, has been framed using the *International Classification of Functioning, Health and Disability (ICF)* model (Jette, 2006; WHO, 2001). The ICF conceptual framework models a dynamic relationship between intrinsic conditions of an individual and the associated functional capacity to engage and participate in daily living and societal roles. The ICF identifies three dynamic components contributing to the overall health of an individual: body function/structure, activity/participation and social/contextual factors. For children with disabilities, emphasis is placed on activity and participation and how to optimize function within these domains. However, activity and participation have not be universally operationalized in the literature, making it more challenging to tease apart the effects of each domain on overall health. Further, there is a paucity of literature defining these constructs within the scope of PA. Gaining a holistic view of an individual's health and well-being is dependent on revealing how these ICF domains interact and facilitate optimal health outcomes. In the context of PA participation among children with physical disabilities, research has focused primarily on the direct effect variance in body function and structure, such as deficits in gross motor function, have on overall participation levels. In turn, physical characteristics or delays in motor function (intrinsic body structure or function) have been proposed to have a cascade effect on activity capacity (what a skills or tasks a child can execute) and participation. Need for effective PA promotion strategies warrants an in depth examination of the underlying pathways from physical function to activity and participation for children with physical disabilities.

The aim of this chapter is to synthesize existing literature on the pathways to PA participation in children with physical disabilities, framed within the ICF model. While the author acknowledges the dynamic, bi-directional relationship between health domains, this discussion will focus on how function and activity impact participation within the context of PA. Determinants of PA that map onto the ICF framework will be discussed first followed by discussion of how change in the body function-structure and activity domains may impact participation for children with physical disabilities.

Function and Diagnosis

Body function/structure describes the physiological function of body structures and anatomical components of an individual (WHO; 2001) and is closely tied to intrinsic biological condition and health status. Low participation and activity levels have been attributed to poor cardiorespiratory levels (Fowler et al. 2007), low muscular strength (Kim and Park, 2011; Fowler et al. 2007), and high spasticity (Kim and Park, 2011) in children with physical disabilities. Notably, Law and colleagues (2004) found that diagnosis was not a predictor of participation among children with central nervous system-related and musculoskeletal disorders including, but not limited to, cerebral palsy, spina bifida, amputation, hydrocephalus and spina cord injury. Rather researchers revealed age, gender and individual physical functional ability as primary predictors for how often a child participated in informal, recreational, social and skill-based activities outside of school (Law et al., 2004). This is consistent with literature supporting gross motor functional levels (i.e. task execution) and physical ability as the strongest determinants of participation among children with disabilities (Palisano et al., 2011). Therefore, intrinsic body function and structures may place unique constraints on this population but do not independently explain the discrepancy in intensity of participation of children with physical disabilities compared to peers.

Activity

Determinants of participation such as gross motor function and physical ability align with the *activity* ICF domain. *Activity* is the functional execution of a goal-oriented task both in a controlled setting (activity *capacity*) and in the context of daily living (activity *performance*).

Activity Capacity. Activity capacity has been operationally defined for this population as the ability to execute gross motor tasks such as rolling over, transitioning from sit to stand, and walking up stairs. Individual physical ability (i.e. gross motor function level) is a strong predictor for overall time spent in PA weekly among children with physical disabilities (Bult, Verschuren, Jongmans, Lindeman, & Ketelaar, 2011; Palisano et al., 2011) and children with cerebral palsy (Keawutan, Bell, Davies, & Boyd, 2014; Maher et al., 2007), suggesting a direct pathway between activity capacity and participation. Palisano et al. (2011) reported that gross motor functional levels accounted for 79% of variance in the number of structured recreational activities performed within the last four months reported by a representative sample of children with cerebral palsy. Narrowing our scope to PA participation, it may be that a specific subset of gross motor functional skills known as fundamental motor skills (FMS) are more relevant as participation determinants. FMS are defined as a set of rudimentary locomotor and object control gross motor skills that include running, jumping, throwing, catching, and kicking (Clark & Metcalfe, 2002; Stodden et al., 2008). Compared to gross motor functional measures, which emphasizes mobility, FMS proficiency assessments describe more activity-specific motor skill movement patterns related to children's play and PA (Ulrich, 2000). Children with motor deficits tend to score lower on FMS assessments (Ulrich, 2000), with lower FMS proficiency shown to predict lower PA levels in typically developing children (Fisher et al., 2005; Wrotniak et al., 2006). Poor motor skills in children with physical disabilities is consequently posited to account for lower PA levels compared to peers. This direct effect of FMS proficiency to PA levels has been supported in a small sample (n=31) of children with cerebral palsy (Capio et al., 2012). Further research is needed, however, to systematically examine the direct effect of FMS proficiency on PA levels for a more diverse group of children with physical disabilities.

Evidence in support of the direct pathway has shown a positive association between FMS proficiency and overall time spent in PA among typically developing children. Looking closer at the literature, this effect has shown to be only weakly significant and appears to be non-linear (Fisher et al. 2005; Wrotniak et al., 2006). Wrotniak and colleagues (2006) observed a strong predictive relationship between variables for children who performed in the lowest and highest quartiles on FMS assessments. This evidence supports poor motor skill proficiency as a potential leading determinant of PA participation in children with physical disabilities. However, the underlying mechanisms as to why and how FMS proficiency translates to greater participation remains unknown. Knowledge of this pathway would advise on how best to support skill development among children with physical disabilities and facilitate positive PA outcomes.

When examined in isolation, physical ability or severity of functional limitations does not serve as a significant indictor for intensity of PA participation (Palisano et al., 2011; Zwier et al., 2010). Low PA participation can thus be partially attributed to poor function and deficits in activity capacity, but these two factors do not alone explain the variability in PA levels for this group. Further, it appears that motor skill proficiency presents as a unique determinant for children demonstrating delays and deficits in motor development.

Activity Performance. On proposed mechanism explaining the link between motor skill capacity and PA participation is *activity performance,* what skills/tasks a child actually does on a day-to-day basis in an activity setting. Activity performance is focused on task execution within the context in daily living, which differs from 'participation' describing involvement in life situations such as social roles and community involvement (Coster & Khetani, 2008). Thus, activity performance is distinguished from capacity and participation as it involves the execution of gross motor skills in structured and leisure PA opportunities.

Bjornson et al. (2013) found that for ambulatory children with CP, *activity performance,* defined by frequency a child executed functional tasks on a daily basis, mediates approximately 75% of the effect of gross motor functional levels on participation in general life situations (intensity and diversity of school, home and community engagement). While this model relates to broader categories of activity and participation, it is plausible that parallel pathway exists when considering FMS and the specific context of PA. This hypothesis aligns with motor development approaches, such as those proposed by Clark and Metcalfe (2002) and Stodden and colleagues (2008). Proficiency in FMS is posited to lay the foundation for children to develop more complex, sport-specific movement patterns required for engagement in sport and recreational opportunities. Greater skill proficiency thereby facilitates greater frequency of skill use during play and the accumulation of greater time in high-intensity PA. Children who fail to achieve high competency in basic motor skills, such as those with physical disabilities, may consequently use motor skills less frequently during an activity opportunity (i.e. poor performance) and engage in less structured PA opportunities, accounting for the discrepancy in PA levels compared to peers with higher motor competencies.

Evidence supports this discrepancy in both overall time in PA and types of activities reported by children with and without disabilities. Children with physical disabilities are significantly more likely to report a greater portion of total PA time spent involvement in informal, low intensity activities than structured, high intensity activities, with the inverse being true for peers without disabilities (Law et al., 2006; Maher et al., 2007; Palisano, Copeland, & Galuppi, 2007; Palisano et al., 2011). Thus lower functional-activity capacities (what gross and fundamental motor skills a child can execute in isolation) in children with physical disabilities may contribute to low participation and explain the large discrepancy in intensity and type of activities when compared to typically developing peers.

To date, however, no studies have systematically examined the indirect pathway of FMS proficiency to PA level through activity performance (i.e. FMS use during a PA opportunity). This mechanism is more relevant in the context of structured opportunities (i.e. organized sport or recreational activities) as it is assumed that children engage at higher intensity levels during structured activity and this engagement is a greater contributor to overall PA levels than informal activity. It is known that children with disabilities are less likely to report time in structured PA, but it remains unclear if their actual skill performance patterns would effectively explain the associated lower PA levels. In fact, we know very little about how higher FMS proficiency might translate to greater PA for children with disabilities. Developmental models proposed by Clarke and Metclafe (2002) and Stodden and colleagues (2008) and empirically supported parallel models by Bjornson et al. 2013, strongly suggests that motor skill performance in a structured PA setting would mediate the effect of FMS proficiency on PA participation. However, to date this mediator model has not been empirically tested.

Conclusion

This review of the current literature on pathways to participation among children with physical disabilities, within the ICF framework, has identified a critical need to directly examine activity performance in structured PA for this population. An examination of direct and indirect pathways to PA participation related to motor skill capacity (what skills can be achieved) and performance (what skills are achieved in life context) (Jette, 2006; Grunland et al. 2012; Coster & Khetani, 2008) is warranted. As such, evidence presented here lends support to the aims of the present study. Positive associations between activity-capacity, as measured by gross motor function and FMS proficiency, and overall time spent in PA, suggest a viable means by which to promote PA participation in children with physical disabilities. However, motor skill proficiency does not entirely account for the discrepancy in intensity and type of PA opportunities reported by children with physical disabilities. Consequently, there is need to examine the mechanisms that may more effectively explain the effect of FMS proficiency on PA levels. Recent advocacy for developing “activity-based strategies” to promote optimal health, physical function and focus on prevention of secondary conditions among children with disabilities support this initiative (Damiano, 2006; Rimmer & Rowland, 2008). Knowledge of how activity performance during structured PA sessions relates to participation will provide valuable insight into how to appropriately design ‘activity-based’ interventions to promote optimal health outcomes for children with physical disabilities. The aim of the present research further contributes to the literature through preliminary investigation of the influence of FMS performance on the relationship between FMS proficiency and PA levels among children with physical disabilities.

Chapter 3: Methods

Study Design

This cross-sectional descriptive study examined the underlying mediating effects of performance on the effect of motor skill proficiency on PA levels in ambulatory children who identified with having a physical disability.

Participants

A total of 10 participants were recruited for this study based on the following inclusion criteria: child was (1) between 5 and <18 years; (2) identified with having a disability that impacted motor function (per parental report), and (3) was independently ambulatory with or without use of an assistive device. Children were determined ineligible for participation if a co-occurring neurological disease or medical condition was present and that was counter-indicative for engagement in MVPA, as determined by parental report of child health and/ or any physical activity restrictions.

Convenience sampling was used in this investigation due to time and resource restrictions. Participants were recruited directly from an adapted physical activity program for children and youth with disabilities at a major University in Oregon. Approval for this study was obtained from the institutional review board. Consent was obtained from all parents/ legal guardians and all child participants assented to participate in this research study.

Procedure

Participants were invited for an initial assessment, which included all primary outcome measures, with subsequent observation at their next attendance to the adapted physical activity program for children at the University, which was a part of the data collection procedures. During the initial assessment , parental consent and child assent were obtained, prior to engagement in any study activities. Pertinent demographic information was collected and participants were assessed for fundamental motor skill proficiency using standardized testing protocol for the TGMD-3 (Ulrich, in press). Participants then attended the adapted physical activity program as they typically would. During their routine activity session, all children engaged in a 10-minute structured station activity targeting performance of 5 selected motor skills: running, jumping, kicking, catching and throwing (Barnett, van Beurden, Morgan, Brooks & Beard, 2009). Study participants were monitored during this time with accelerometers worn on the participant's right hip and video-recorded for later assessment of select FMS performance frequency while participating in the physical activity program.

The adapted physical activity program is held in a university gymnasium on Friday evenings, led by adapted physical education (APE) teachers-in-training and includes a 1:1 ratio of undergraduate student volunteers to child participants. Participants are divided into age groups of approximately 8-10 children and spend 30 minutes in the gymnasium and 30 minutes in the pool. Time spent in the gymnasium is divided into 5-10 minutes of instructional time and 20 minutes of group engagement in structured activity, supported by paired volunteers. Activities are targeted at promoting motor skill fitness and optimal participation in all children, and ample options for adaptive equipment and activity modification are provided to accommodate various skill and ability levels.

The activity program group leaders and volunteers were blinded to the aims of this investigation. All were provided a detailed description of the 10-minute motor-skill activity, the goals of each station, and strategies for modifying skill level and promoting high-intensity activity (e.g. running to retrieve ball after throwing it or quickly moving to a new position after each catch). Group leaders incorporated this activity into their lesson plans immediately following warm-up. This approach was taken to provide consistent opportunity for use of target motor skills across sessions and participants. The motor skill activity involved children rotating through 5 motor skill stations: (1) running 50 feet between cones, (2) kicking a soccer ball into a goal, (3) throwing a ball through a free standing ring, (4) long jumping along a taped ladder on the floor, and (5) playing catch with a partner. These skills were selected based on previous empirical support of output proficiency in object control skills (i.e. catching, kicking and throwing) as a significant predictor for PA levels in children (Barnett et al., 2009), skill-specific PA participation (Raundsepp & Päll, 2006), and with the inclusion of jumping, health-related fitness in young adults (Stodden, Langendorfer, & Roberton, 2009). Furthermore, this select skill set has been shown to predict PA in children with CP (Capio et al., 2012) and are assumed to be highly used in sports and recreational activities.

Appendix A illustrates the activity station set up. Rotation through stations was cued by music. A song played 45 seconds indicating children should perform the activity at their current station and then paused for 15 seconds cuing transition to the next station (counter-clockwise rotation). All participants in the entire program were familiar with this activity structure from exposure during winter 2015 activity session pilot testing. All structured activity sessions were monitored by the lead student researcher to ensure quality and consistency of activity implementation.

Instruments Used

Motor Skill Proficiency. *FMS* proficiency was evaluated using the *Test of Gross Motor Development, third edition* (TGMD-3) (Ulrich, in press). The TGMD-3 is a standardized assessment of goal-oriented fundamental, gross motor skills and is comprised of two subtest: locomotor skills (run, gallop, hop, skip, horizontal jump, and slide) and object control skills (two hand strike stationary ball, forehand strike of self-bounced ball, one hand stationary dribble, two hand catch, kick a stationary ball, overhand throw and underhand throw/toss) (Ulrich, in press). Participants are scored based on demonstration of movement patterns consistent with 4-5 specific skill criteria along a dichotomous scale: “0” criterion not met and “1” criterion met. Verbal instruction is provided with skill demonstration by a trained administrator. Two consecutive trial attempts are then scored and summed to produce a raw skill score. Skill scores are totaled to generate locomotor and object control subtest scores and combined for a raw total gross motor test score (Ulrich, in press). Raw locomotor and object control subset scores can be transformed to standard scores and added to produce a total gross motor quotient score based on normative data. However, due to the TGMD-3 normative data not being available within the timeline of this investigation, as well as exceeding the target age range (5-17 years) extending beyond the age restrictions of the assessment (3-10 years), raw scores will be used to represent FMS proficiency in data analysis. While the TGMD-3 is still under review, the TGMD-2 is strongly supported as a valid and reliable measure of motor skill (Evaggelinou, Tsigillis, & Papa, 2002; Ulrich, 2000) and has been shown to be sensitive to detecting differences among children with motor delays (Ulrich, 2000), such as children with cerebral palsy (Capio, Sit, & Abernethy, 2011).

Motor Skill Performance. A momentary time sampling system was used to code participant’s FMS performance during structured PA opportunities. Video recordings of 10-minute activity participation were uploaded to iMovie. Videos were edited and overlaid with a colored border that alternates between green (record interval) and red (observe interval) on a 6-second record/6-second observe interval, respectively (adapted from Logan, Robinson, Webster, & Barber, 2013; McKenzie, 2009; 2012; Smith, *dissertation*). A research assistant and the lead researcher, trained in TGMD-3 assessment and skill performance observation procedure, coded performance from the videos. Types of skills coded for during the “6-second record” intervals aligned with skill types on the TGMD-3 (i.e. run, jump, catch, throw, etc.). Skills were coded along a dichotomous scale (‘0’ not performed; “1” performed), with performance qualified as skill execution broadly consistent with the specific skill criteria on the TGMD-3. Each skill-type category was limited to one performance mark per 6-second record interval, with potential for more than one skill-type category to be marked within any given interval. This frequency count method was adopted to limit discrepancies between discrete (e.g. throw) and continuous (e.g. running, dribbling) skills. For example, during a basketball game, if the child is running and dribbling a ‘1’ count will be added to the respective skill categories for that given record interval. The score sheet is provided in Appendix B.

Additionally, each interval was coded for on-task behavior, with a ‘1’ denoting a child’s behavior was consistent with the goal of the activity station, such as performing a skill, waiting in line, or learning about the skill movement from their volunteer partner and a 0 indicating the child was off-task or demonstrating an unrelated behavior. Time on-task behavior was cross-referenced to ensure low performance frequency were not attributable to poor participant adherence to activity instructions.

Physical Activity Level. PA levels was evaluated using accelerometers. The ActiGraph® GTX3+ (Pensacola, Fl.) will be provided to all participants and worn on their right hip during observed participation in the activity session. Compliance with this instruction was cross-referenced with research assistants’ reports and video assessment notes regarding times when accelerometer monitor was not worn correctly. Accelerometry is intended to provide an objective measure of physical activity (Godfrey, Conway, Meagher, & O’laighin, 2008) and predicts intensity of movement over a specific interval of time. ActiGraph® software measures intensity of movement in counts that can be divided into activity-intensity categories (sedentary, light, moderate and moderate-to-vigorous physical activity (MVPA)) (Freedson, Pober & Janz, 2005). Accelerometers are widely used in PA studies for typically developing children (Godfrey et al. 2008; Dollman, Okely, Hardy, Timperio, Salmon & Hills, 2009) and have been shown to be a valid and reliable measure of physical activity for children with developmental disabilities (Kim & Yun, 2009) and children with cerebral palsy (Capio et al, 2012).

Furthermore, the *System for Observing Fitness Instruction Time (SOFIT)* (McKenzie, 2009; 2012) was used as a secondary measure of physical activity and to ensure quality and consistency of the 10-15-minute activity across sessions. The lead researcher observed each structured activity session and evaluate the general activity level of the group using a 12-second momentary sampling rate, with each child being randomly selected and observed for 2 minutes. PA level was scored along a modified SOFIT 3-level scale (Smith, *dissertation*): Sedentary (standing or sitting, no energy expenditure), Light (walking, isolated limb movement), and Moderate-to-Vigorous (running, high energy expenditure) (denoted S, W, V respectively on the coding sheet in Appendix B; Smith, *dissertation*). Individual PA levels of participants were coded with the SOFIT from videos, using the same system described above, as a secondary measure to accelerometry.

Data Reduction

Accelerometry data collected during the 10-minute activity was reduced into PA intensity categories using the following cut points: sedentary (≤ 100 counts), light (> 100 counts), moderate-to-vigorous (≥ 500 counts) (Freedson, Pober, & Janz, 2005), given the age and type of activities the targeted population engaged in (Trost, Loprinzi, Moore, & Pfeiffer, 2011). Continuous zeros over a period greater than 5 minutes were considered non-wear time (Jeong, *dissertation*) and cross-referenced for participant compliancy with research assistant reports and video-data. Data confirmed for non-wear was excluded from the final dataset. The average time spent in moderate-vigorous PA (≥ 500 counts) during the 10-minute motor skill activity was used in primary data analysis to represent PA participation level.

Video analysis was conducted by a trained research assistant, familiar with the 6-second observe/6-second record interval coding system (adapted from Logan et al., 2013 and McKenzie, 2012). Inter-rater reliability of >80% was established through pilot data testing prior to the onset of this study.

A maximum of 50 intervals were coded per participant for the three mutually exclusive events: motor skill performance, SOFIT activity level, and on-task behavior. FMS performance was further quantified as average frequency of skills performed during the 10-minute activity. To account for difference in the total time observed in the activity (e.g. variability due to group leader ending activity early or poor visibility in video analysis), frequency of motor skill use was calculated as total skill performance counts divided by total time child was observed (maximum of 10 minutes):

$$Performance\ Frequency = \frac{total\ skill\ count}{total\ time\ observed\ during\ activity}$$

A parallel system was used to quantify MVPA level as percent of total intervals observed in which child was coded for SOFIT in moderate-to-vigorous intensity category (V):

$$MVPA_{SOFIT} = \frac{total\ intervals\ scored\ 'V'}{total\ number\ of\ intervals\ observed\ during\ activity}$$

Statistical Analysis

An initial correlation analysis was conducted to examine the relationship between variables within each of the targeted domains: motor skill capacity, motor skill performance and

PA participation level. In SPSS software version 22.0, with an alpha of 0.05 determined *a priori*, relations between these domains were calculated with Pearson's Product Moment Correlation between each of the variables illustrated in Figure 3. Relationship A represents the extent to which a child's quality of motor skill execution is associated with use of skills during activity and calculated for raw TGMD-3 Total Gross Motor, Locomotor, Object Control, and Select Skills scores and frequency of motor skill use during activity, respectively. Relationship B represents the extent to which a child's motor skill use relates to their overall PA intensity level during the activity. Relationship B was compared frequency of motor skill use to percent time and percent of SOFIT intervals coded for MVPA. Relationship C describes the degree to which a child's quality of motor skill execution relates to intensity of PA participation, and was calculated using TGMD-3 Total Scores and PA level. Finally, to explore the relationship between motor skills and PA in more depth, the correlations (A, B, C) were run a second time using individual skill scores for run, jump, kick, catch and throw. Visual analysis of scatterplots for select variable pairs was conducted to examine sample distribution and assist in the interpretation of the relationship between proficiency, performance and participation domains.

Two mediation models were conducted to test the indirect effect of motor skill proficiency (TGMD-3 score) on physical activity level (percent time in MVPA) through motor skill performance (frequency count of skill use) (see figure 2B). This model was tested using a SPSS ordinary least squares path analysis, PROCESS, that examines direct and indirect effects of the path from the predictors to the outcome variable (Hayes, 2013). Compared to traditional causal steps mediation analysis (Baron & Kenny, 1986), PROCESS accounts for violations of the normality assumption and low power issues due to small samples by use of bootstrapping and inclusion of multiple mediation and control variables in models (Hayes, 2009; 2013). As is illustrated in Figure 2B, TGMD-3 Raw Total Gross Motor Score was used at the predictor variable and FMS performance frequency during activity (defined by the total number of skills performed per minute). The outcome variable of PA level was represented by percent time spent in MVPA, as measured by accelerometer, in the primary analysis and by direct observation SOFIT-MVPA scores in the secondary analysis. Although gender and age are recognized as covariates in motor skill proficiency and PA levels (Malina, 2014), we were not powered to include these variables in our analysis. A standardized effect size, kappa squared (κ^2, Preacher & Kelley, 2011), for the indirect effect of motor skill proficiency on participation (*ab)* was tested using a conventional number of bootstrap samples (10,000) (Hayes, 2013). κ^2 represents the ratio of the standardized effect size relative to maximum possible effect given the sample variance and magnitudes of relationships between model variables, it is independent of sample size, and is the recommended approach in examining indirect effect in mediation analysis (Hayes, 2013; Preacher & Kelley, 2011). κ^2 is bound by 0 and 1, with κ^2 approaching 1 interpreted as the indirect effect being as large as it could have potentially been given the design and data variance (Preacher & Kelley, 2011). Cohen's 1998 effect size cut-offs, 0.01, 0.09, and 0.25, will be used to gage the magnitude of the effect size as small, medium or large, respectively, per best practice recommendations (Preacher & Kelley, 2011). The following equations represent the direct and indirect paths of FMS proficiency to PA level and are diagramed in figure 2B (adopted from Hayes, 2013):

$$FMS_{Performance} = i_1 + aFMS_{Proficiency} + e_M$$

$$PA_{level} = i_2 + c'FMS_{Proficiency} + bFMS_{Performance} + e_Y$$

Where i_1 and i_2 are regression intercepts, e_M and e_Y are errors in estimation of performance and PA level respectively, and a, b, and c' are regression coefficients.

Chapter 4: Results

This sample consisted of 10 children (6 males, 4 females) with disabilities who identified with having a disability that impacted physical function, per parental report, all of whom regularly participated in the adapted physical activity program (range 1-10 years of attendance). Per eligibility criteria, participants were independently ambulatory (GMFCS level 1 or 2), and were between the ages of 5 to <18 years of age (M=11.69, SD=4.1, Range 5.57-16.83 years). Notably, 8 of the 10 parents identified their child as having developmental delay. Sample characteristics are reported in Table 1.

The mean scores for the primary measures of motor skill proficiency (TGMD-3 total scores), motor skill performance (frequency of skill use in activity) and PA participation level (accelerometer and SOFIT scores) are presented in Table 2. Scores on the TGMD-3 were all below the total possible score, indicating participants within this sample have not to date achieved mastery or developed mature movement patterns for the assessed fundamental motor skills. The variability in proficiency scores was highest for object control (M=48.0, SD=13.1, range: 17.0-49.0) and concurrently for total gross motor (sum of object control and locomotor scores) (M=28.1, SD=10.1, range: 33.0-74.0). During the structured activity, children performed on average one skill per minute, and were for the majority of time on-task (M=85.7% of activity time, SD=14.3%) and engaged in MVPA (M=86.3% of activity time, SD=14.5%).

[Insert table 2]

Figure 4 illustrates Pearson's product-moment correlations for the relationships between key variable scores in motor proficiency, performance and PA participation domains. No significant correlations were found between any of the variables and age or gender. Notably all relationships were positive indicating greater motor skill proficiency was associated with higher frequency of skill use and higher percent time in MVPA, for both accelerometry and direct observation outcomes. Similarly, greater motor skill performance was associated with higher percent time in MVPA, reaching statistical significance for direct observation SOFIT score (r=0.734; n=10, *p*=0.0016). Aside from this evident relationship, the strongest correlations were observed between frequency of skill performance and both total gross motor scores (r=0.61, n=10, *p= 0.060*) and object control subtest total score (r = 0.579, n=10, *p=0.080*).

[Insert figure 4]

A secondary correlation analysis to examine relationships in terms of specific motor skill was conducted. The strongest correlations were observed between PA Level and motor skill proficiency scores for the run (r = 0.646, n=9, *p=0.060*) and the jump (r = 0.778, n=9, *p= 0.013*). No notable correlations were revealed between total observed performance count of specific skills and percent time in MPVA for either accelerometry or direct observation.

Although correlation analysis did not reveal any significant relationships between motor skill proficiency, performance and physical activity participation, the planned mediation analysis was conducted. The contemporary pathway analysis approach to mediation by Hayes (2013) supports exploration of mediation effects in the absence of existing relationships between variables in attempt to uncover potential mechanisms of behavior. Within the primary mediation model, TGMD-3 total gross motor raw score represented the predictor variable, frequency of skill use served as the mediator variable and percent time in MVPA was used as the output variable. As illustrated in Figure 5 and Table 3, participants who demonstrated greater capability in executing motor skills in an isolated testing did *not* significantly differ in number of motor skills performed per minute (*a* = 0.047*)*, and participants equivalent in motor skills performance rates during the activity did *not* differ significantly in the percent time spent MVPA (*b*= 3.76).

Regardless, our real interest was in whether our data supports that motor proficiency is effecting PA participation via motor skill activity performance. A bias-corrected 95% bootstrap confidence interval [-0.274 – 1.518] for the observed indirect effect (*ab*= 0.175), based on 10,000 bootstrap samples does not support this claim. Rather it suggests motor skill performance is *not* influencing the variance observed in PA participation as measured by acceleromerty. The standardized kappa-squared ($\kappa^2 = 0.143$, *95% CI* [0.0016-0.5515]) indicates the observed indirect effect is about 14% as large as its maximum possible value given the conditional constraints relative to sample variables in the model (Hayes, 2013; Preacher & Kelley, 2011). Based on this analysis, motor skill proficiency was not independently effecting percent time in MVPA (i.e. direct effect; $c' = 0.218$, $p = 0.667$). In sum, the results of the primary analysis do *not* support motor skill performance as a mechanism through which motor skill proficiency is transmitting an effect on PA participation level, as measured by accelerometry (i.e. no evidence of mediation).

[Insert figure 5 and table 3]

A planned secondary mediation analysis was conducted substituting accelerometry output data with direct observation scores of PA behavior (i.e. SOFIT scores) as the outcome variable. The results of this analysis are reported in Table 4. Note the sample size for this model was n=10, compared to the primary analysis in which accelerometry data was missing for one child. In this model, the observed indirect effect (*ab*= 0.175), based on 10,000 bootstrap samples, suggests the variance in the observed PA level can be significantly accounted for by the effect of motor skill proficiency through motor skill performance (*95% CI* [0.001 – 0.009]). Kappa-squared ($\kappa^2 = 0.632$, *95% CI* [0.188 – 0.879]) indicates an effect size 63% the size of its maximum possible value (Hayes, 2013; Preacher & Kelley, 2011), and a moderate (trending towards strong) mediation effect (Preacher & Kelley, 2011). Thus, when PA level is measured through direct observation, motor skill performance is supported as a significant mechanism through which motor skill proficiency effects participation outcomes. However, caution is advised when interpreting these results given the small sample size and significant positive correlation between frequency of motor skill use and SOFIT PA scores. This limitation is addressed in more detail in the discussion.

[Insert table 4]

Chapter 5: Discussion

This investigation is unique in its effort to examine the relationship between ICF domains within the specific context of PA among children with disabilities. Previous research has revealed weak but significant relationships among children with physical disabilities between weekly PA levels and gross motor function (Bult et al., 2011; Keawutan et al., 2014) and fundamental motor skill proficiency levels (Capio et al., 2012). To gain a better understanding of the mechanism of this pathway, this investigation examined the extent to which a child's *proficiency* in executing FMS in an isolated, controlled setting facilitated greater PA levels through actual *performance* or use of select motor skills during a structured activity opportunity. Acknowledging the limitations of this small sample, results from our secondary mediation analysis offer initial evidence that a child's proficiency in FMS influences their rate of skill use during structured PA, which in turn facilitates greater observed PA levels. This lends to a critical discussion on the relationship between ICF activity and participation domains in the context of PA and disability. Recognizing the influence of motor skill ability on participation level for children with disabilities has implications on how decisions are made regarding support and services when facilitating PA for this at risk population. Our results, in alignment with previous research (Bjornson, 2013; Holsbeeke et al., 2009; Young et al., 1996), suggest skill performance during activity is distinctly different from what happens in isolated assessment settings, and has a substantial influence on PA participation. Thereby indicating a need to target motor skill development within the context of PA programs, such as is practiced in participation-based therapy approaches (e.g. Palisano, Chiarello, King, Novak, Stoner, & Fiss, 2012). Focus on performance in child-relevant settings may allow for more effective strategies for increasing the concerning low PA levels reported among children with disabilities than isolated skill development approaches.

The discrepancy in evidence for a mediation effect between our primary (accelerometry) and secondary (direct observation) models challenges definitive interpretations of results. However, examining these results alongside evidence for positive associations between ICF domains lends insight on a potential pathway through which PA is facilitated. First, previous research has shown significant associations between activity capacity and performance domains (Bjornson et al., 2013, Holsbeeke et al., 2009, Young et al., 2009). The observed trend associating greater motor skill proficiency with higher motor skill performance frequency suggests this relationship holds true when considering PA-specific behaviors. Second, greater variability in performance rate, relative to proficiency scores, indicate that a child's ability to execute an isolated skill does not translate directly into use of that skill during PA. In other words, equivalent proficiency scores among two children does not imply identical skill performance patterns during activity. Consistent with previous finding (Holsbeeke et al., 2009; Tieman, Palisano, Gracely, & Rosenbaum, 2004; Young et al., 1996), this result emphasizes the important influence of context on activity outcomes. Our results add to this body of literature (e.g. Tieman et al., 2004), showing the assessment of a child's motor skills within standardized, controlled settings is not congruent with what a child is actually achieving (i.e. number of skill attempts or intensity of play) while engaged in an adapted physical activity program.

Third, low variability in the percent of time children were engaged in MVPA, as measured by accelerometry, offers promising evidence that PA programs can facilitate attainment of desired MVPA levels among children who have not yet mastered FMS. As indicated by scores on the TGMD-3 for locomotor and object control subtests well below mastery (Table 2), our sample was experiencing developmental delays in motor skills. Despite this, all but one participant achieved >80% time in MVPA. The weak correlations between proficiency scores and PA levels ($r < 0.50$, $p > 0.10$) lends to this interpretation. Although not the intended aim of this investigation, this evidence indirectly addresses one of the top 5 research questions in motor development posed by Malina (2014): whether PA programs for children are able to counteract the proposed skill proficiency barrier (Stodden, 2008; Wall, 2004) and ensure equal opportunity to achieve desired PA levels. The high PA levels observed in our sample may be attributable to the structure of the adaptive physical activity program which provides individual support for each child and ample opportunity to modify equipment and activity goals. Further work is needed to examine specific program characteristics supporting positive PA behavior in more depth.

Identifying the relative contribution of locomotor and object control skills may further inform the design of PA promotion programs. Object control, and specifically ball handling skills, tend to be more demanding tasks requiring greater control of movement and thus, mastery is proposed to develop later and facilitate engagement in more complex movement patterns in structured PA to a greater extent than locomotor skills (Wall, 2004; Westendorp et al., 2011). The observed larger positive, moderate association ($r = 0.58$, $p = 0.080$) within our sample between object control skill proficiency and activity performance aligns with this developmental hypothesis. Conversely, PA levels had a stronger association with locomotor ($r = 0.486$, $p = 0.185$) than object control ($r = 0.229$, $p = 0.554$) proficiency scores. It is difficult to extract from our data the relative influence of locomotor and object control motor skills on activity performance. Especially given that the majority of the stations (3 of 5) in the 10-minute structured activity (*see* Appendix A) targeted object control skills (kick, throw and catch) and may be largely accounting for the observed relationships between proficiency, performance and participation. Future research is needed to examine the relative influence of object control and locomotor skills on activity performance and PA participation patterns.

Notably, there was a discrepancy in results for evidence of a mediation pathway between accelerometry and direct observation measures of MVPA. Authors offer two potential explanations. First, there was greater variability in direct observation (i.e. SOFIT) PA scores, increasing power to detect patterns within our sample. Second, direct observation scores may provide a more accurate representation of PA level for children with disabilities due to limitations surrounding the establishment of accelerometer cut-points. Accelerometers predict energy expenditure and associated PA level from activity counts. Freedson et al.'s (2005) cut-points were developed from calibration studies in which children without disabilities performed walk and run tasks on a treadmill, in a laboratory setting. Although Freedson et al. (2005) has been supported for use in field-based studies (Trost et al., 2011), two limitations challenge the appropriateness of these cut-points for our sample. First, the 10-minute activity comprised of a greater range of skills that included isolated body movements (kick, throw and catch) likely not accounted for in the initial calibration study. Second, there is little evidence available to support the use of these cut-points in the assessment of PA for children with physical disabilities, whose movement patterns may be very distinct from typically developing peers. Thus, while accelerometry was the primary measure within this investigation, direct observation with SOFIT may have provided a better approximation of time spent in MVPA for this population.

SOFIT allows for direct observation and systematic sampling of children's participation in activity and codes PA levels based on observed upper and lower body movements. Momentary time sampling rates of 60 seconds or less for SOFIT have been shown to provide strong estimates of MVPA behavior (Pope, Coleman, Gonzalez, Barron, & Heath, 2002) among children in physical education class settings (McKenzie, 2009; McNamee, *dissertation*). Sensitivity of the measure increases with lower sampling rates. The nature of the target skills (isolated skills performed in short burst of energy) and the short duration of the activity (10 minutes) used in this investigation justified adoption of sampling rate of 12 seconds. In effect, the SOFIT may have captured PA behavior more accurately within our sample, and likely accounts for the discrepancy in results between the two PA outcome measures. More in depth examination of appropriate objective and direct observation PA measures for children with disabilities in structured PA bouts is needed to support further investigation of pathways facilitating participation.

An important corollary of this question of appropriate measurement selection is the operationalization of PA participation for children with disabilities. Present PA discrepancies for children with disabilities within the literature relate to lower overall attendance patterns and average PA intensity across the week (Imms, Reilly, Carlin, & Dodd, 2008; Law et al., 2004; Palisano et al., 2011; Zwier et al., 2010). This study, alternatively, focused on one specific 10-minute activity bout to allow for direct evaluation of behavior patterns *during* activity. In doing so, the relationship between ICF domains in a specific context was more closely examined, but the extent to which findings can be generalized to broader PA participation patterns is limited. FMS are generally associated with high intensity sport-specific activities and recreation (e.g. soccer, basketball). Thus, deficits in FMS that hinder application of these skills in context-specific PA opportunities may further link to reduced overall MVPA levels (Stodden et al. 2008, Wall, 2004). It would be of considerable value for future investigations to examine how the observed relationship between motor skill proficiency and participation, and the mediating effect of activity performance, compares across relevant-PA contexts and weekly participation patterns.

Limitations

Alongside a small sample size, several limitations exist for the present investigation. First, the small sample size cautions the generalization of findings to the broader population of children with disabilities. Furthermore, the small sample was assumed to be representative of all ambulatory children experiencing functional limitations when using bootstrapping within mediation analysis. A single outlier has potential to greatly influence the sampling distribution for bootstrapping and subsequently distort findings. Replication of this study with a larger more diverse sample is needed to confirm the indirect effect of FMS proficiency to PA participation, through motor skill performance in activity. Second, results for this indirect pathway does not provide any indication for causality. Does motor skill deficits reduce performance in PA and in turn participation levels, as proposed in developmental models, or does limited engagement in PA opportunities (low PA) reduce opportunity to use skills and hinder development of motor skills? Our results indirectly indicate MVPA can be facilitated by adaptive physical activity programs regardless of skill level, weakening the argument for a definitive causal link between domains. Further investigations, including intervention studies, are needed to reveal the cause-effect relationship between motor skill deficits and lower PA participation in children with physical disabilities and the relative influence of program design.

Third, while observation scores for PA were coded as mutually exclusive from motor skill performance patterns, the measures themselves are not distinct from one other. Both SOFIT scores and FMS counts were obtained from direct observation of movement patterns, such that if a child was jumping in the ‘record’ interval they were coded for vigorous PA on the SOFIT scale and a FMS count. This explains the strong correlation between these measures and suggests a potential measurement co-dependency issue. The absence of a significant correlation between SOFIT scores and accelerometer data is unexpected and further complicates the interpretation of results. Validity evidence for SOFIT has been founded on comparable results to objective PA measures such as accelerometers (McKenzie, 2012; Pope, Coleman, Gonzalez, Barron, & Heath, 2002). As discussed above, the properties of each measure in relation to the sensitivity to capture the specific movement patterns used in the 10-minute activity likely contributes to this discrepancy. Careful consideration is needed in subsequent research in selecting appropriate PA measures.

On a final note, the design of the structured activity limits generalization to other PA opportunities, such as organized sport and recreation. The structured activity stations (*see* Appendix A) were chosen to ensure equal opportunity for all participants to perform target motor skills but does not represent the complex motor skill activity demands discussed in motor development literature (Clark & Metcalfe, 2002; Stodden et al., 2008; Wall, 2004). For example, the station requiring the child to perform kick the ball into a net does not have the same task demands as a soccer game. In effect this design allowed for comparison of a child's capacity to execute the target motor skill in an isolated, controlled setting to their ability to perform that skill in a personally-relevant PA context, and relate this to PA level. Consequently, the activity may not have had high enough skill demands to impose a 'proficiency barrier' or to directly capture the impact of skill proficiency on participation. This in turn may account for the low variability in MVPA observed in our sample and may not accurately reflect the PA levels achieved in more traditional structured PA settings (i.e. recreational or organized sports). Future research is needed to extend this model to examine the influence of motor skill proficiency and performance when the demands and complexity of the activity are increased, such as in team games requiring combination skill patterns (i.e. running and kicking in a soccer game).

Chapter 6: Conclusion

The concern for low PA participation among children with disabilities warrants substantial investigation of the mechanisms that account for this discrepancy. The ICF provides framework through which to discuss the direct and indirect relationships between what children are optimally able to accomplish, what they are actually doing in their daily routines, and the extent to which they are achieving desired levels of engagement in child-relevant physical activities. Traditionally, daily participation level has been largely attributed to individual skill capacity levels, with intervention strategies targeting development of isolated motor skills, such as in physical therapy settings. However, our results advocate for a distinction between activity capacity and actual performance of skills in child-relevant contexts to be made. Identifying performance in PA as a mechanism by which a child's capacity to achieve motor skills translates to greater participation levels, shifts focus to the development of these skills within the activity setting and places emphasis on the importance of context. Further research is needed to establish the motor skill pathways influencing PA levels for children with disabilities to more effectively guide participation promotion strategies.

Figures

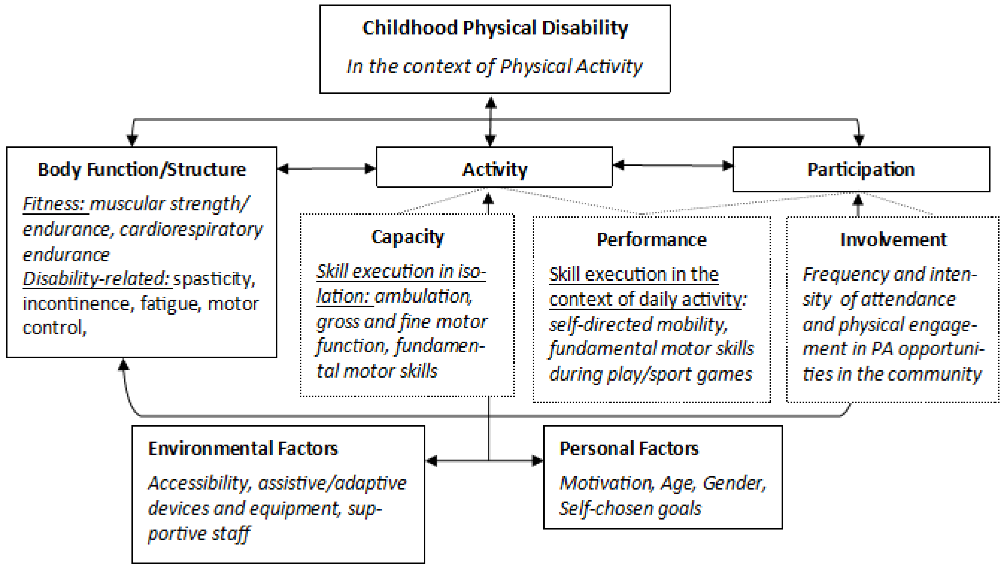

Figure 1. International Classification of Functioning, Health and Disability (ICF) framework for children with physical disabilities in relation to PA. **Bolded** text indicates the ICF domains and *italicized* text provides examples of operationalizing physical activity within each domain (Badley, 2008; McBurney et al., 2003; Ploeg et al., 2012; Rimmer, 2006; Rosenbaum & Stewart, 2004; Temple, 2010; WHO, 2001, 2013)

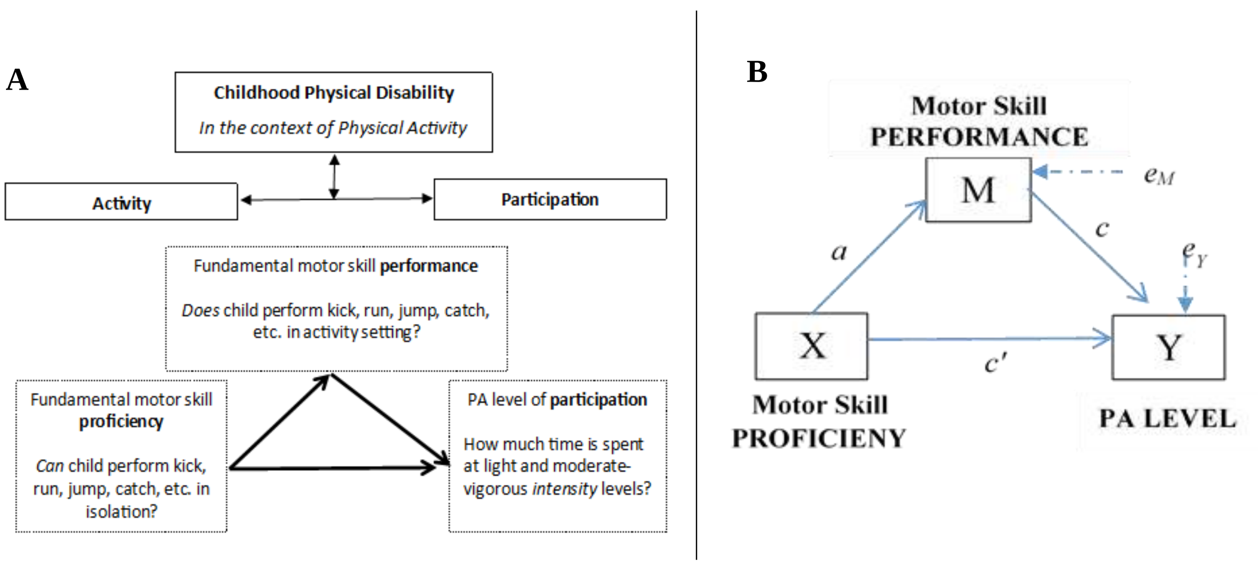

Figure 2. The proposed (A) conceptual model and (B) associated statistical simple mediation model, for the direct (*c'*) and indirect effects (*ab*) of motor skill proficiency on physical activity (PA) participation level in children with physical disabilities. Where *a, b, and c'* represent and e_y represent error estimates.

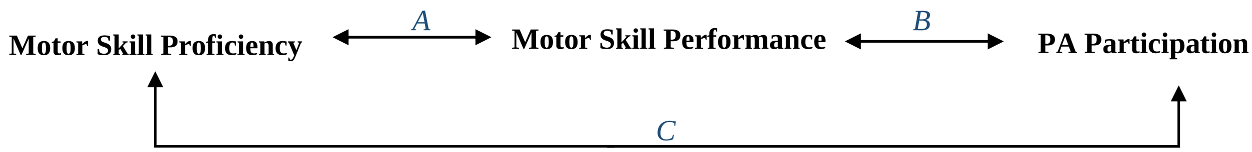

Figure 3. Graphical presentation of the proposed correlational analysis comparing relationships between **(A)** motor skill proficiency and motor skill performance, **(B)** motor skill performance and physical activity (PA) participation levels and **(C)** motor skill proficiency and PA participation.

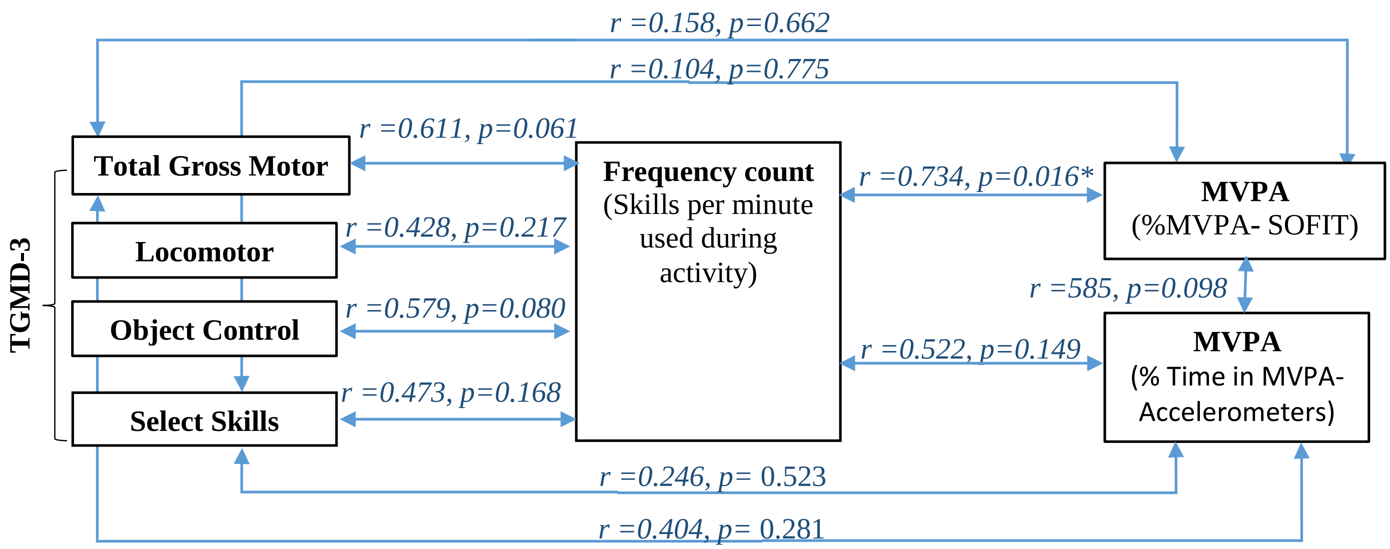

Figure 4. Pearson's r correlation between motor proficiency (TGMD-3 Total Gross Motor and Select Skill raw scores), motor performance (frequency of skill use during activity) and physical activity participation level (percent time in moderate-to-vigorous physical activity (MVPA) as measure by accelerometers and direct observation, SOFIT).

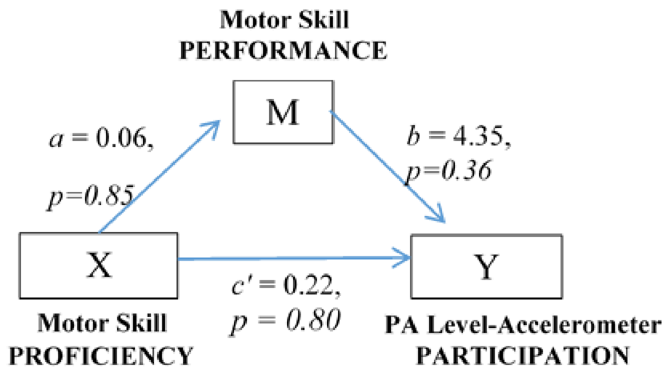

Figure 5. Simple mediation model for the influence of motor skill performance (M) on the effect of motor skill proficiency (X) on PA participation level (Y) (primary measure). NOTE: Conducted using an ordinary least squares path analysis, PROCESS SPSS (v22.0) 95% confidence intervals bias-corrected and based on a 10,000 bootstrap sample. (Hayes, 2013).

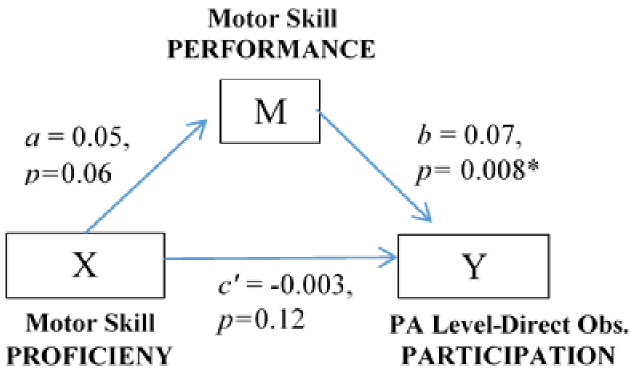

Figure 6. Simple mediation model for the influence of motor skill performance (M) on the effect of motor skill proficiency (X) on PA participation level (Y) (secondary measure) NOTE: Conducted using an ordinary least squares path analysis, PROCESS in SPSS (v22.0) 95% confidence intervals bias-corrected and based on a 10,000 bootstrap sample. (Hayes, 2013).

Tables

Table 1

Sample Characteristics (N=10)

Variable	N
Gender	
Male	6
Female	4
Age	5.75-16.83 years (mean=11.69, SD=4.1)
Diagnosis (*parental report)*	
Ethlers-Danlos Syndrome	5
Dyspraxia	1
Fetal Alcohol Syndrome	2
Autism Spectrum Disorder	1
Traumatic Brain Injury	1
GMFCS Level	
I	8
II	2
Ethnicity	
White	10
Other	0
Income	
$30,001-$38,000	5
$54,001-$62,000	1
$70,001 or more	2
Declined Response	2

Table 2

Mean Scores, SD and Range for Motor Skill Proficiency and Performance, and Physical Activity Level

Variables	N	M(SD)	Range (total possible score)
Motor Skill Proficiency			
TGMD-3	10		
Total Gross Motor Raw Score		48.0 (13.1)	33.0 – 74.0 (100)
Total Locomotor Raw Score		19.9 (5.1)	11.0 – 28.0 (46)
Total Object Control Raw Score		28.1 (10.1)	17.0 – 49.0 (54)
Select Skill Summed Score (run+ jump+ kick+ catch+ throw)		15.1 (4.9)	10.0 – 26.0 (38)
Motor Skill Performance			
Total number of select skill used during activity	10	22.0 (13.1)	0.0 – 37.0
Frequency of skill use (skill / min observed)		0.94 (1.1)	0.0 – 3.37
Physical Activity Participation Level			
Accelerometer (% of total time in activity)	9		
Sedentary		6.8 (9.7)	0.0 – 31.8
Light		6.8 (5.6)	0.0 – 18.2
Moderate-to-Vigorous		86.3 (14.5)	50.0 – 97.7
SOFIT (% of intervals observed)	10		
Sedentary		10.4 (7.7)	0.0 – 27.0
Light		40.2 (7.8)	24.0 – 52.0
Moderate-to-Vigorous		50.9 (14.8)	50.9 – 76

Table 3

Primary Mediation Model Coefficients-- for the direct and indirect effects of motor skill proficiency (X) on physical activity (PA) participation (Y) through motor skill performance (M).

	Outcome					
	M (Performance)			**Y** (PA Level **– Accelerometer)**		
Predictor	*Coefficient*	*Std. Error*	*p*	*Coefficient*	*Std. Error*	*p*
X (Proficiency)	*a* 0.060	0.027	0.851	*c'* 0.219	0.254	0.808
M (Performance)	---	---	---	*b* 5.35	5.44	0.361
Constant	i_2 -0.270	1.293	0.061	i_2 67.81	18.669	0.012*
	R^2= 0.413			R^2= 0.281		
	F (1, 7)= 4.99, *p*= 0.061			F (2, 6)= 1.160, *p*=0.372		

	Effect	*Bootstrap Std. Error*	*95% Bootstrap CI*	κ^2 *(95% CI)*
Indirect Effect	*ab* 0.324	0.491	-0.123 – 1.899	0.244 (0.0154- 0.813)

Table 4

Secondary Mediation Model Coefficients-- for the direct and indirect effects of motor skill proficiency (X) on physical activity (PA) participation (Y) through motor skill performance (M).

	Outcome					
	M (Performance)			**Y** (PA Level- **SOFIT**)		
Predictor	*Coefficient*	*Std. Error*	*p*	*Coefficient*	*Std. Error*	*p*
X (Proficiency)	*a* 0.053	0.024	0.061	*c'* -0.003	0.002	0.135
M (Performance)	---	---	---	*b* 0.070	0.019	0.008
Constant	i_2 0.000	1.202	0.999	i_2 0.059	0.064	0.386
	R^2= 0.373			R^2= 0.672		
	F (1, 8)=4.76, *p*= 0.061			F (2, 7)= 7.183, *p*=0.0201		

	Effect	*Bootstrap Std. Error*	*95% Bootstrap CI*	κ^2 *(95% CI)*
Indirect Effect	*ab* 0.0037	0.0019	0.0010 – 0.0090	0.633 (0.188 - 0.878)

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APPENDIX A

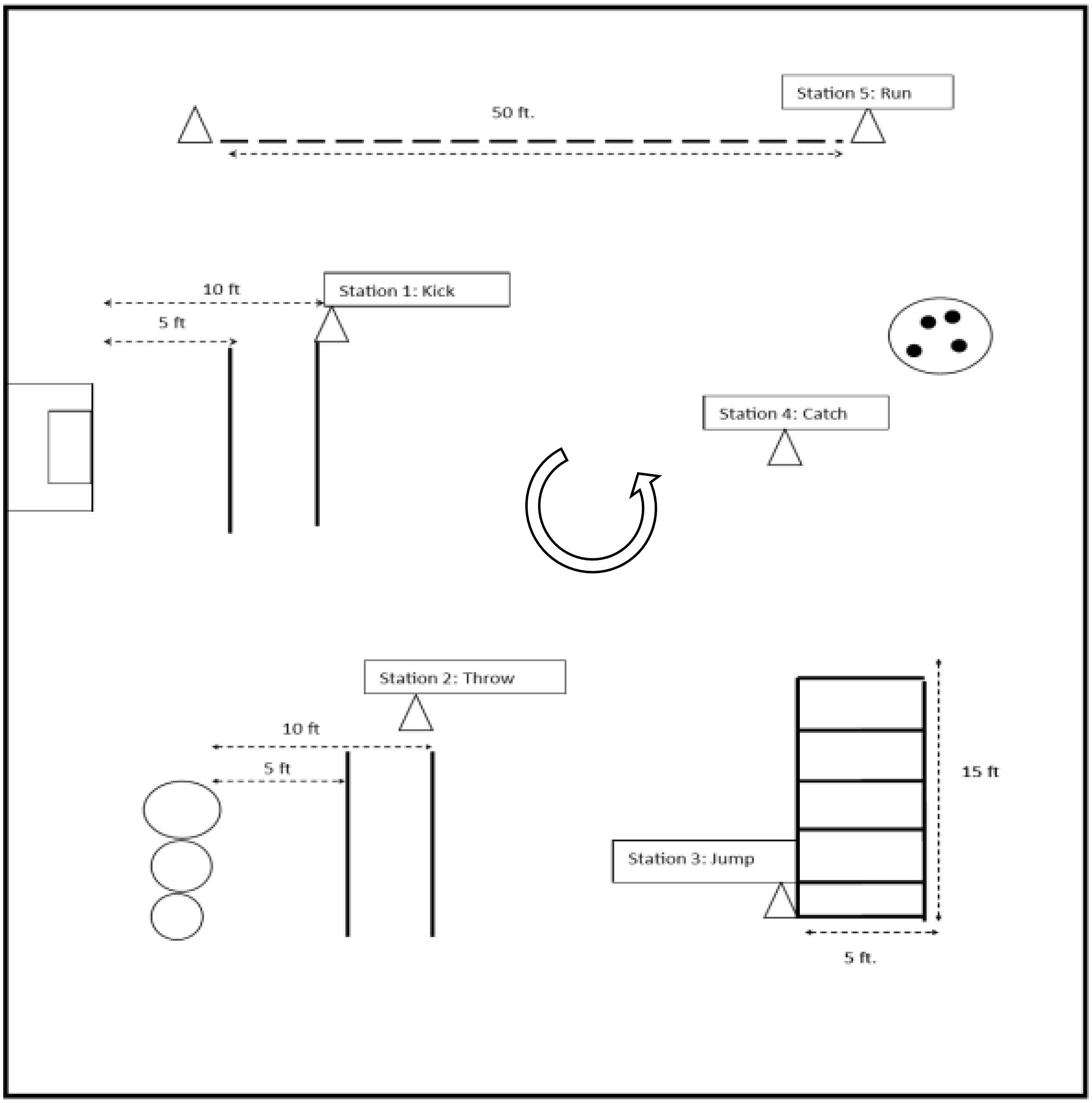
Physical Activity Lesson Plan

Where: IMPACT
Time: 10 Minutes
Goal: Promote use of fundamental motor skills (running, jumping, kicking, catching, throwing) and engagement in moderate-to-vigorous physical activity
Station Rotation: prompted by music to rotate stations every 45 seconds (music will play 45 seconds and then pause for 15 seconds to cue transition to next station)
Notes:

- Students should be prompted to self-select
  - (a) Starting station
  - (b) Activity level/difficulty at each station
- Volunteers/Instructors should prompt students to
  - (a) Choose appropriate activity level/difficulty
  - (b) Complete each task, emphasizing quality over speed
  - (c) Motivate engagement in MVPA by encouraging students to <u>run between stations, run to retrieve ball, move positions (i.e. starting point) after each skill attempt</u>
  - (d) Encourage student to get through course <u>at least once</u>

Station	Target Skill	Activity Directions	Equipment	Set-Up
1	Kick	"**Kick** the ball at the goal OR to partner 3-5 times"	Soccer Balls Foam Soccer Balls Soccer Net/Goal	Tape parallel lines 5ft and 10 ft away from the wall Set out soccer net and cones for "goal" Place sign with directions at station
2	Overhand Throw	"**Throw** the ball at the target OR to a partner 3-5 times"	Foam Balls Tennis Balls Whiffle Balls Quittach Hoops	Tape parallel lines 5ft and 10 ft away from red line Set out three hoops of different sizes on the red line Place sign with directions at station
3	Horizontal Jump	"Starting on your spot or by a cone **Jump** as far as you can 3-5 times"	Floor Tape	Tape ladder 15 feet long- 5 feet wide with rungs every 1 foot Place sign with directions at station
4	Two-Handed Catch	"Throw the beanbag/scarf up and **catch** it OR have a partner throw it to you and **catch** it 3-5 times"	Hula-Hoop Beanbags Foam Balls	Set Hula-Hoop on floor with beanbags and foam balls close to sign. Place sign with directions at station
5	Run	"**Run** as fast as you can to the cone and back"	Cones	Set up cones at the end of the gym 20-30 feet apart

Physical Activity Blue Print



APPENDIX B

IMPACT PERFORMANCE CODING SHEET

Participant ID#__________

Date of performance coding___________ *Coder ID: _______________*

Name of Video File Associated with this sheet:____

☐ ______ *Entered in Project6616_Master Data Sheet (Check and Date when complete)*

			SOFIT			**On-Task Behavior**	**Motor Skill Performance**						
Minute	**Interval**	**Child Visibility**	Seden-tary	Light	MVPA	1=yes 0=no	Run	Jump	Kick	Catch	Throw	No skill obs.	Total
	1		S	W	V								
	2		S	W	V								
	3		S	W	V								
	4		S	W	V								
1	5		S	W	V								
	6		S	W	V								
	7		S	W	V								
	8		S	W	V								
	9		S	W	V								
2	10		S	W	V								
	11		S	W	V								
	12		S	W	V								
	13		S	W	V								
	14		S	W	V								
3	15		S	W	V								
	16		S	W	V								
	17		S	W	V								
	18		S	W	V								
	19		S	W	V								
4	20		S	W	V								
	21		S	W	V								
	22		S	W	V								
	23		S	W	V								
	24		S	W	V								
5	25		S	W	V								
	26		S	W	V								
	27		S	W	V								
	28		S	W	V								
	29		S	W	V								
6	30		S	W	V								

Min.	Interval		Sed.	Light	MVPA	On-Task	Run	Jump	Kick	Catch	Throw	No skills	Total
	31		S	W	V								
	32		S	W	V								
	33		S	W	V								
	34		S	W	V								
7	35		S	W	V								
	36		S	W	V								
	37		S	W	V								
	38		S	W	V								
	39		S	W	V								
8	40		S	W	V								
	41		S	W	V								
	42		S	W	V								
	43		S	W	V								
	44		S	W	V								
9	45		S	W	V								
	46		S	W	V								
	47		S	W	V								
	48		S	W	V								
	49		S	W	V								
10	50		S	W	V								
		TOTAL											

Notes: